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| 10/528,556 | 10/05/2005 | Yasuyuki Sakaguchi | Q72116 | 6382 |

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| EXAMINER | |
|---|---|
| MALEKZADEH, SEYED MASOUD | |
| **ART UNIT** | **PAPER NUMBER** |
| 1722 | |

| SHORTENED STATUTORY PERIOD OF RESPONSE | MAIL DATE | DELIVERY MODE |
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**Please find below and/or attached an Office communication concerning this application or proceeding.**

If NO period for reply is specified above, the maximum statutory period will apply and will expire 6 MONTHS from the mailing date of this communication.

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| Office Action Summary | Application No. 10/528,556 | Applicant(s) SAKAGUCHI ET AL. | |
|---|---|---|---|
| | Examiner SEYED MASOUD MALEKZADEH | Art Unit 1722 | |

*-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --*

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.
- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

**Status**

1)☒ Responsive to communication(s) filed on 05 October 2005.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

4)☒ Claim(s) 1-15 is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) 1-15 is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

**Application Papers**

9)☒ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on 05 October 2005 is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. § 119**

12)☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☒ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

**Attachment(s)**

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date 05/10/2005.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

## DETAILED ACTION

### *Priority*

Receipt is acknowledged of papers submitted under 35 U.S.C. 119(a)-(d), which papers have been placed of record in the file.

### *Claim Objections*

Claim 3 and 4 are objected to because of the following informalities:

In both claims, the number, which is used to identify "growth crucible" in drawing, is not shown correctly. Appropriate correction is required.

### *Claim Rejections - 35 USC § 103*

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

The factual inquiries set forth in *Graham* **v.** *John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.
3. Resolving the level of ordinary skill in the pertinent art.
4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

Claim 1 and 15 are rejected under 35 U.S.C. 103(a) as being unpatentable over Davis et al (US 4,866,005) in view of Hung Chi Chang et al (US 3,275,415)

Davis et al ('005) teaches "a method of forming large device quality single crystals of silicon carbide. The sublimation process is enhanced by maintaining a constant polytype composition in the source materials, selected size distribution in the source materials, by specific preparation of the growth surface of seed crystals, and by controlling the thermal gradient between the source materials and the seed crystal" (See abstract). It further teaches a single seed crystal of silicon carbide having a desired polytype and silicon carbide source powder are introduced into a system such as the sublimation crucible and furnace (See lines 36-40, column 6). Moreover, it discloses "Once the silicon carbide source and the seed crystal are introduced, the temperature of the silicon carbide source powder is raised to a temperature sufficient for silicon carbide to sublime from the source powder, typically a temperature on the order of 2300 degree centigrade while the temperature of the source powder is being raised, the temperature of the growth surface of the seed crystal is likewise raised to a temperature approaching the temperature of the source powder, but lower than the temperature of the source powder and lower than at which silicon carbide will sublime"(See lines 30-42, column 7). Also Davis ('005) discloses the invention comprises introducing the seed single crystal of silicon carbide of a desired polytype and a silicon carbide source powder into a sublimation system (See lines 56-59, column 8). Furthermore," it discloses during the sublimation growth process, gas species which

contain silicon carbide evolve near the hotter top of the crucible and are transported via the thermal gradient to the seed at its respective lower temperature in the cooler lower portion of the crucible" (See lines 8-13, column 9). It further illustrate, the porous graphite liner is formed in such a manner as to provide an annular chamber between lower portions of the porous graphite liner, the crucible walls and the crucible lid. A central sublimation chamber is also showed (Lines 55-60, column 5 and Figure 1). Moreover, a sublimation crucible is typically used in conjunction with a sublimation furnace (See lines 24-26 and figure 6). Further it illustrates an apparatus, which can be used to accomplish the methods of the Davis et al ('005) invention (See lines 65-68, column 10 and figure 4, 5, and 6). It further teaches "an apparatus for the preparation of relatively large single crystals of a decomposing compound, in combination, a casing containing a charge for producing vapors of the compound, heating means for heating the charge to a temperature at which vapors of the compound are evolved, a small empty hollow member having closed ends disposed in the charge so that the said vapors contact the walls of the hollow member having a porosity to admit passage of predetermined amounts of the said vapors into the hollow" (See lines 23-30, column 11) wherein the hollow member comprises a hollow cylinder of graphite with graphite end disks, and the charge produces vapors of silicon carbide (See lines 43-46, column 11). Moreover, It further discloses "when silicon carbide sublimes, it forms three basic vaporized materials: Si, $SiC_2$ or $Si_2$C. Depending upon the poly-type of the source powder, the amount or flux of each of the species which is generated will differ" (See

lines 55-60, column 6). However, it does not teach an atmosphere gas surrounding the growth crucible contains silicon.

In the analogous art, Hung Chi Chang et al ('415) discloses an invention which relates to the preparation of single crystals from the vapor phase of compounds that decompose such, for example, as silicon carbide, and in particular it concerns novel apparatus and methods for preparing such single crystal (See lines 12-17, column 1). It further teaches, an important factor is the provision of adequate flow of silicon carbide vapors through the walls of the cylinder (See lines 47-49, column 7). Moreover, it teaches " predetermined nucleation sites can be provided by providing a concentration of silicon on the inside surface of the graphite cylinder. Spots or strip films of silicon serve this purpose adequately. These conveniently are applied by painting dabs of silicon at the desired locations. As a result of the presence of these high local concentrations of silicon, concentration of silicon carbide vapor develop at those sites and crystals are nucleated there preferentially to other areas on the surface where no such silicon concentration is present. While the silicon eventually vaporizes completely during the process, its evaporation is a rate phenomenon and enough silicon is present for an initial period of time that is adequate to bring about the initial nucleation" (See lines 53-67, column 8). Furthermore, it discloses, "In a furnace of growing single crystals of silicon carbide, in combination, a cylindrical vessel constructed to contain a charge of material selected from the group consisting of at least one of the group consisting of silicon carbide and mixtures of silicon and carbon, heating means disposed symmetrically about the vertical axis of the vessel whereby to heat a transverse portion

of the charge to a temperature wherein vapors of the silicon carbide are evolved, said transverse portion being at a higher temperature than adjacent portions of the charge, a small empty hollow closed end cylinder of graphite disposed within the charge within the cylindrical vessel at the said transverse portion, the transverse portion intersecting the hollow graphic cylinder intermediate its ends, the walls of the hollow graphite cylinder being porous to the vapors of silicon carbide whereby predetermined amounts of silicon carbide vapor penetrate through the graphite walls into the hollow space" (See lines 47-60, column 11 and 1-6, column 12). Hung Chi Chang et al ('415) further teaches, "a centrally disposed in the vessel is a thin-walled, hollow cylinder. Surrounding the cylinder is a mass forming a charge of raw materials. These can be a silicon carbide particles, such as commercial silicon carbide crystals, or a mixture of elemental silicon and carbon, or both" (See lines 19-24, column 3). The vessel can be any shape desired, and it is made of heat resistant metal capable of being substantially gas tight at elevated temperatures while the inside surface of vessel is heat insulated as by having a mass of fine particles of carbon or graphite disposed against it, or graphite felt (See lines 58-64 column 2), and Cylinder is made of commercially available, high purity graphite, as by machining such a shape form a block of graphite (See lines 40-44, column 3). Also it teaches, the mass of raw materials including the graphite cylinder is disposed in a container such as a carbon crucible, to provide support for the outside surface of the raw material mass (See lines 12-15, column 4 and figure 2). It further teaches, "The temperature of the crucible is raised from below 2000°C to about 2500°C in about 10

minutes. The silicon carbide around the graphite cylinder will volatilize rapidly" (See lines 64-68, column 5).

It would have been obvious to one of ordinary skill in this art at the time of applicant's invention to include a surrounding of a silicon gas around the growth crucible of Davis et al ('005) as suggested by Hung Chi Chang et al ('415) in order to reduce the amount of defects in SiC single crystal.

Claim 2 is rejected under 35 U.S.C. 103(a) as being unpatentable over Davis et al (US 4,866,005) and Hung Chi Chang et al (US 3,275,415) in view of Shiomi et al (US 6,193,797).

Davis et al ('005) and Hung Chi Chang et al ('415) disclose a method for producing a silicon carbide single crystal with the limitations as discussed above. However, they do not teach the silicon carbide single crystal is grown, with vapor pressure of silicon gas in the growth crucible maintained substantially equal to or higher than equilibrium vapor pressure of silicon gas in the gas sublimated from the silicon carbide raw material.

In the analogous art, Shiomi ('797) teaches a method of making an SiC single crystal and apparatus for making SiC single crystal in which high-quality SiC suitable for semiconductor electronic components is grown (See lines 5-10, Column 1). It further shows a graph, which the vapor pressure of Si is higher than that of $SiC_2$ or $Si_2C$ occurring during the generation of SiC (See lines 33-36, column 2 and figure 5).

It would have been obvious to one of ordinary skill in this art at the time of applicant's invention to set the vapor pressure of silicon gas in the growth crucible of

Davis et al ('005) and Hung Chi Chang et al ('415) maintained substantially equal to or higher than equilibrium vapor pressure of silicon gas in the gas sublimated from the silicon carbide raw material in the growth crucible as suggested by Shiomi ('797) in order to enhance the SiC forming speed.

Claims 3-5, 7-10, and 12-14 are rejected under 35 U.S.C. 103(a) as being unpatentable over Davis et al (US 4,866,005) and Hung Chi Chang et al (US 3,275,415) in view of Shigeto et al (Pub No: US 2001/0004877).

Davis et al ('005) and Hung Chi Chang et al ('415) disclose a method and apparatus for producing a silicon carbide single crystal with limitations as discussed above. Moreover, it discloses "Once the silicon carbide source and the seed crystal are introduced, the temperature of the silicon carbide source powder is raised to a temperature sufficient for silicon carbide to sublime from the source powder, typically a temperature on the order of 2300 degree centigrade while the temperature of the source powder is being raised, the temperature of the growth surface of the seed crystal is likewise raised to a temperature approaching the temperature of the source powder, but lower than the temperature of the source powder and lower than at which silicon carbide will sublime"(See lines 30-42, column 7). Further it illustrates an apparatus, which can be used to accomplish the methods of the Davis et al ('005) invention (See lines 65-68, column 10 and figure 4, 5, and 6). It further teaches "an apparatus for the preparation of relatively large single crystals of a decomposing compound, in combination, a casing containing a charge for producing vapors of the compound, heating means for heating the charge to a temperature at which vapors of the compound are evolved, a small

empty hollow member having closed ends disposed in the charge so that the said vapors contact the walls of the hollow member having a porosity to admit passage of predetermined amounts of the said vapors into the hollow" (See lines 23-30, column 11) wherein the hollow member comprises a hollow cylinder of graphite with graphite end disks, and the charge produces vapors of silicon carbide (See lines 43-46, column 11). However, they don't teach continuously feeding a silicon raw material from outside into the space and also evaporating the silicon raw material. They also do not teach the silicon raw material feed rate and the amount of atmosphere gas pressure surrounding the growth crucible of SiC.

In the analogous art, Shigeto et al ('877) discloses "a method and an apparatus for producing a silicon carbide single crystal. More particularly, it relates to a method and an apparatus for producing a silicon carbide single crystal wherein a silicon raw material is allowed to continuously react with a carbon raw material to generate gas, from which a silicon carbide single crystal grows" (See paragraph [0003]). It further teaches there is provided a method for producing a silicon carbide single crystal comprising allowing a silicon raw material to react with a carbon raw material in a reaction crucible to generate reaction gas, that reaches a seed crystal substrate on which a silicon carbide single crystal grows, characterized in that the silicon raw material is continuously fed onto the carbon raw material which is maintained at a temperature such that carbon is allowed to react with silicon in a molten state or gaseous state to generate the reaction gas (See paragraph [0017]). Moreover, it teaches, "it is preferable that the silicon raw material of finely divided particle form is fed

onto the carbon raw material of a finely divided particle form, and that the carbon raw material is maintained at a temperature of 1900 degree centigrade or higher" (See paragraph [0018]). It also discloses, "a schematic view showing an example of a single crystal production apparatus of the invention, to which a silicon raw material feeder is attached" (See paragraph [0021]). It further discloses "to maintain such an excessive state, it is only necessary to set a feeding rate of the silicon raw material to or lower than a rate of reaction of the silicon raw material to be gasified. In the case of employing a feeding system by providing feeding intervals for a feeding method, this method can be realized by setting the quantity of one feeding operation equal to or lower than a value obtained by the product of a feeding interval and a gasifying rate. The gasifying rate varies depending on crystal growth conditions, but the rate is set substantially to form 0.1 mg/s to 5 mg/s in the later-described working examples" (See paragraph [0032]). Also it discloses " production of a silicon carbide single crystal can be carried out by setting a total pressure (which is substantially same as the total pressure in the reaction crucible and the raw material) of the production apparatus from a high pressure reaction to a level slightly higher than the normal pressure, i.e., within the range of (0.01 to 1,000) x 133 pa. Especially, to efficiently generate reactive gas, (1 to 300) x133 Pa is preferable (See paragraph [0052]).

It would have been obvious to one of ordinary skill in this art at the time of applicant's invention to include a continuous feeding stage of silicon raw material from outside into the space between outer and growth crucible in SiC production method and apparatus of Davis et al ('005) and Hung Chi Chang et al ('415) as suggested by

Shigeto et al ('877) in order to continuous production of SiC single crystal and also to increase the quality, efficiency, and production rate of SiC.

Claim 6 is rejected under 35 U.S.C. 103(a) as being unpatentable over Davis et al (US 4,866,005) and Hung Chi Chang et al (US 3,275,415) in view of Shigeto et al (US 6,406,539).

Davis et al ('005) and Hung Chi Chang et al ('415) disclose a method for producing a silicon carbide single crystal with limitations as discussed above. However, they do not teach the silicon raw material feed from outside into the space in solid form has powder particles by having a diameter of 0.2 to 5 mm.

In the analogous art, Shigeto et al ('539) discloses "a process for producing a silicon carbide single crystal and a production apparatus therefore, in which a silicon material is reacted with a carbon material to yield a silicon carbide single crystal, and more specifically, to a process for producing a silicon carbide single crystal and a production apparatus therefore, in which a melted or vaporized silicon material is introduced into a carbon material in order to generate a silicon carbide gas, which is then caused to reach a silicon carbide seed crystal substrate to thereby grow a silicon carbide single crystal" (See lines 13-23, column 1). It further discloses the process for producing a silicon carbide single crystal, wherein that the powdery/ granular carbon material is a carbon granule having an average grain size of 100 μm to 5 mm (See lines 1-6, column 4). It further discloses, "When the grain size is less than 100 μm, the powdery/granular carbon material passes through the performed plate and becomes unable to be held thereby. In addition, the flow rate of the silicon gas passing through

the powdery/granular carbon material decreases, resulting in a decreases crystal growth rate. When the grain size is greater than 5 mm, the area of contact with the silicon gas that passes through the powdery/ granular carbon material without causing a reaction increases, and the reaction between the powdery/granular carbon material and the silicon gas does not proceed uniformly, with the result that the composition of a grown silicon carbide single crystal deviates form the tachometric composition" (See lines 46-59, column 6).

It would have been obvious to one of ordinary skill in this art at the time of applicant's invention to size the powder used as a silicon raw material of Davis et al ('005) and Hung Chi Chang et al ('415) in between a diameter of 0.2 to 5 mm suggested by Shigeto et al ('539) in order to increase the evaporation rate of silicon particles.

Claim 11 is rejected under 35 U.S.C. 103(a) as being unpatentable over Davis et al (US 4,866,005), Hung Chi Chang et al (US 3,275,415), Shigeto et al. (Pub No: US 2001/0004877) and further in view of Vodakov et al (US 6,428,621)

Davis et al ('005) and Hung Chi Chang et al ('415) disclose a method for producing a silicon carbide single crystal with the limitations as discussed above. However, they do not teach growth rate of the silicon carbide single crystal is 1mm/hour or more.

In the analogous art, Vodakov et al ('621) discloses, "a low defect density silicon carbide (SiC) is provided as well as an apparatus and method for growing the same. The SiC crystal, growing using sublimation techniques, is preferably divided into two stages of growth" (See abstract). It further discloses "preferably the axial temperature

gradient, i.e., the gradient between the source and the growth surface, is in the range of 10°C to 50°C per centimeter, yielding the desired normal growth rate of between 0.4 and 1.5 millimeters per hour (See lines 42-46, column 8). The invention further teaches, "A SiC material is provided with a low defect density, defects including both dislocations and micropipes. The defect density in the grown SiC is less than 10,000 per square centimeter, preferably less than 1000 per square centimeter, more preferably less than 100 per square centimeter" (See lines 36-40, column 2).

It would have been obvious to one of ordinary skill in this art at the time of applicant's invention to determine the growth rate and micropipe density SiC in SiC production method of Davis et al ('005), Hung Chi Chang et al ('415), and Shigeto et al ('877) as suggested by Vodakov et al ('621) in order to control the variables in production method of SiC to make the production method more efficient and higher quality.

### *Conclusion*

The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Seyed Masoud Malekzadeh whose telephone number is 571-272-6215. The examiner can normally be reached on Monday – Friday at 8:30 am – 5:00 pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Yogendra N. Gupta can be reached on (571) 272-1316. The fax number for the organization where this application or proceeding is assigned is 571-272-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published application may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance form a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

SMM

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TC 1700